

EcoDrought Webinar: Monitoring the exchange of moisture between the land and atmosphere to improve our understanding of drought

Webinar Transcript

Speakers:

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Ashley Fortune Isham: Good morning, depending on your location, from the U.S. Fish and Wildlife Service's National Conservation Training Center in Shepherdstown, West Virginia.

My name is Ashley Fortune Isham, and I would like to welcome you to our webinar series held in partnership with the U.S. Geological Survey's National Climate Change and Wildlife Science Center, or NCCWSC, located in Reston, Virginia.

The NCCWSC Climate Change Science and Management webinar series highlights their sponsored science projects related to climate change impacts and adaptation and aims to increase awareness and inform participants like you about potential and predicted climate change impacts on fish and wildlife.

I would like to welcome Abby Lynch, who is a research fish biologist with NCCWSC, to introduce today's speakers. Abby?

Abigail Lynch: Hi. Thanks. It's my pleasure to introduce today's two speakers. First, we have Dr. Gabriel Senay, who is the research physical scientist with the U.S. Geological Survey's Earth Resources Observation Science Center.

Senay is co-located with the North Central Climate Science Center in Fort Collins, Colorado and is a faculty affiliate with the Ecosystem Science and Sustainability Department at Colorado State University. He conducts applied research on water use and availability assessment and drought monitoring using satellite-derived data and hydrologic modeling.

Our second speaker for today is Dr. Imtiaz Rangwala, who is the research scientist at the Cooperative Institute for Research in Environmental Sciences at the University of Colorado, Boulder and NOAA's Physical Sciences Division, who leads the climate Foundational Science Area of DOI's North Central Climate Science Center.

He's a climate scientist with training in assessing and diagnosing regional scale climate change. Using climate observations and models, he works to understand and quantify climate processes relevant to regional warming trends and hydrological processes and changes. This specifically ties into understanding climate extremes and changes in water balance in the western U.S., including the Great Plains region, and how these extremes affect ecosystem response.

Other work includes future climate change uncertainty in the context of decision-making and climate adaptation with experience in the development and communication of useful and usable future climate change scenarios for natural resource management.

Dr. Rangwala also has expertise in climate change in high-elevation regions.

Please help me welcome both of our speakers.

Imtiaz Rangwala: Thank you. Am I ready to go?

Ashley: Yes.

Imtiaz: Thank you. This is Imtiaz Rangwala, and I'm happy to present this webinar with my good friend and collaborator Gabriel Senay. We're going to talk about a tale of two products here, and both dealing with drought detection and monitoring, one specifically focused on -- just trying to get to the arrow here, yes -- the evaporative demand term.

The tool is the EDDI tool, which I'll be talking about, and Gabriel will be talking about the evaporative response term, and the tool there is looking at the anomalies in actual evapotranspiration.

Both these tools, their value is, again, they're emerging tools, high-resolution, near real-time, very objective, so just based on algorithm and data that's fed in. However, they need some training for effective interpretation. For that interpretation, I'll just go into some physical concepts before I come back to the EDDI tool, and then Gabriel takes over and discusses his actual ET anomalies tool.

If we just look at the land surface and we look at what are the loss processes for water on a land surface, and you see there is the component of groundwater recharge, or loss to the groundwater, runoff into streams, and then there's a loss to the atmosphere through this process called evapotranspiration, this combination of evaporation and transpiration.

In part, this evapotranspiration term is responding to what we call the evaporative demand of the atmosphere.

I'll spend some time talking about what do we mean by that and how do we measure this evaporative demand term.

Effectively, evaporative demand is a measure of degree to which the atmosphere primarily is trying to evaporate water from the land surface. It's often referred to as the thirst of the atmosphere, also as potential evapotranspiration in literature.

What I'll discuss today is more of this term called the reference evapotranspiration. They used quite a bit in the agricultural systems. That's the measure we use to quantify the EDDI tool.

What's the relevance of evaporative demand to drought? I just want to point out that although EDDI and the tool that Gabriel helped develop, has been primarily used or initially used in the agricultural system, we think it's quite applicable to the ecological system or the non-irrigated systems.

In a regional context, a sustained or emerging high evaporative demand could lead to water stress on the land surface, and that's where the relevance comes.

How do we measure it? There are different ways. In the field, it's primarily measured or estimated to this pan evaporation concept where you have this pan filled with water and you basically...and the loss of water in the pan gives you a measure of the atmospheric evaporative demand.

It's a very useful measure, however, there's a problem of adequate number of observation stations out there and then again it's not responding as the crop would respond, it's just like an open water evaporation. There are some limitations in that regards as well, but that's one real physical measure out there in the field for evaporative demand.

Primarily, in the literature you'll find that it's estimated using some kind of mathematical model for potential evapotranspiration or the reference evapotranspiration. I've listed a few here and they could be pretty complex to simpler forms.

One mathematical model is related to what we call evapotranspiration - estimating that term. What that is, is you have a reference condition under which evaporation happens and you're measuring actual evaporation in the reference condition, given a particular climate.

Here, one that the FAO, the Food and Agricultural Organization uses is a reference grass crop of a certain height. It is just under 10 centimeters here. It's a well-watered system and if you have a certain climatic condition, what is the evapotranspiration from that, and that's a measure of the evaporative demand.

The specific method we used for the EDDI tool is to estimate...The reference evapotranspiration is dependent on the Monteith method and I would assume most of you are pretty familiar with that method. That method is pretty comprehensive in a sense that it's considered a full suite of meteorological variables varying from temperature, rain, sunshine or I would call the net radiation and humidity.

We are finding that this model, the physical model, it captures especially on very fine time scales and a lot of these processes and variability and there's no other models that do that. I'll show you some comparison of that in the next slide.

What you see here is the pan evaporation across the continental US and the mean value of the evaporative demand from May through September, compared to the Monteith based reference ET. What you can see is that it shows in the both part large similarities where you see high magnitudes of evaporative demand in the southwest and the Central Plains region.

You also see quite clearly the trends in high coefficient of variation across the Great Plains region. It's high variability or fluctuations in evaporative demand.

This method, we've been finding to other research work we have done and comparing different methodologies to estimate ET0 that Penman-Monteith is kind of a good measure for ET0.

Getting back to the tool itself to understand drought risk at any particular point in time, it's the EDDI tool, the evaporative demand drought index, and what it shows is how anomalous the evaporative demand is at a particular place you're interested in, relative to a historical period.

The historical period here is the satellite era period for us. That's from 1979 to current. Looking at how anomalous the evaporative demand is can give you an interesting assessment of risk. As you can see right now, there is a high anomaly in ET0 in the southern part of the country, southeastern part of the country and this region of Kansas and Oklahoma where we have seen a lot of wildfires.

Again, that wildfire condition is one risk that EDDI is pretty good at providing this information on. The other stakeholders who are interested in EDDI at this point and could be relevant to the dry land or irrigated agriculture flash drought alert, or just folks who are interested in ecological impact in terms of growth and mortality of vegetation.

How is EDDI calculated? For any region and a time-window that you're interested in, it could be sub-seasonal to seasonal, you get this meteorological input at high resolution that's for operational use, we use a 12-kilometer NLDAS product. There's also the four-kilometer product that's out there for EDDI.

That meteorological input goes to the Penman-Monteith formulation to calculate the reference ET term and that is then taken through the standardization process, because they're not ranked based on barometric method, and that furnishes the EDDI value.

Let me say a little bit about what are some of the characteristics or attributes of EDDI. We show EDDI in these percentile categories, the hot colors are showing drought stress and then the cool colors are showing the lack of it. In fact, that could be used for some flood risk assessment.

These percentile categories are similar to or identical to the ones used in the U.S. Drought Monitor. That's one easy way to interpret it and you can see that the white margin is where you have normal conditions.

One thing that's relevant to interpretation of EDDI and the drought risk that EDDI is pointing to comes from the consideration of timescale. You can look at EDDI from weeks, to months, to seasons, to years. I guess that's why the interpretation is quite salient.

One of the particular strengths of EDDI is to capture these precursor signals of water stress at weekly to monthly timescale. If you're looking at this weekly to one month timescale, you're probably looking at emerging conditions of high evaporative demand or emerging risk of a dry atmosphere from which the stress from the land surface can build up.

If you're looking at much more long term values of EDDI, then what it's pointing to is persistence of a particular drought condition. The emergence with the persistence, and that's the two different

ways to look at EDDI. We often look at different timescales when you're using EDDI to look at how the drought is emerging in the region or how drought stress is emerging.

Seasonality is another issue that's relevant. You can look at the maps in the cold season, and in the warm season. You may have a different sense of concern, I guess such as the...I lost my pointer? OK.

As a general rule, as we are looking at and learning more about EDDI is that we find that as a general rule, we should be more concerned about especially the short term changes in EDDI during the warm season.

I like to take you to a couple examples and show how EDDI could have provided useful information and an early warning. This is looking at the short-term EDDI and comparing it to the USDM and looking at the 2012 drought development in the Midwest regions that's in this box here.

What you see is that EDDI was showing a development of this exceptional drought risk in the Midwest region pretty much two months ahead of where they appear in the U.S. Drought Monitor. We see this lag where drought's threat is seen on the landscape and where the precursor signal from EDDI starts showing up much earlier. That's the early warning attribute of EDDI.

Here's another example from the Wind River Indian Reservation where they had, in 2015 growing season, a miracle May rain episode. It was a very wet period, and then suddenly the region felt a micro-drought emergence during the rest of the warm season, but it didn't show up in the USDM until very late.

When you look at the two-week EDDI plots here, it shows the nature of stress that was felt on the landscape. This was somewhat corroborated by the anecdotes from the stakeholders in the region. Again, another example showing the early warning capability of EDDI.

What's the take-home for EDDI? It's a Standardized Drought Index, works solely with the evaporative demand terms. It's telling us the atmospheric side of the story, in terms of what stress the atmosphere can produce on the land's surface. It's near real-time, so the operational product is just five days behind at this point.

High resolution, so we have 12- and 4-kilometer product. The work supports multiple time scales, so you can look at stuff seasonally, to multi-seasonal drought processes, and understand how the whole risk is evolving over these time scales. As I said earlier, it's effective for early warning and monitoring.

We have several resources for EDDI. I'm just showing the EDDI two-pager slide here, which we wrote in December 2015 and has been pretty visible and widely read. We also have a list of resources at the end of the presentation that we'll show, where you can see other resources.

At this point, I'll hand over to Gabriel to move to discussing the actual ET.

Gabriel Senay: Thank you, Imtiaz. I will focus now on the actual ET, as opposed to the potential ET that Imtiaz has discussed. The main difference is the potential ET is more a driver, and actual ET would be the response of the landscape based on the availability of soil moisture.

We'll have some brief background and some products in Drought Monitor versus ET anomaly comparison. Also, I'll talk about the Missouri River Water Balance that uses the actual ET.

Why ET? When I refer here, ET is going to be the actual ET, as opposed to the potential ET. As I said earlier, it's a response variable as opposed to precipitation or potential ET. It reflects the integrated effect of energy and aerodynamics. That's pretty much the potential ET, but also includes soil moisture, vegetation condition, environmental stress.

All the ones you see on the right hand are the limitations. If you don't have soil moisture, or the vegetation is not in good health, or there is environmental stress like salinity, the vegetation, the landscape cannot evapotranspire, even if the demand is very high. What you see on the left side is the potential ET.

On the left side, you see the energy and the wind relativity, which means a sunny day and drier atmosphere, and the windy atmosphere will have a much higher potential ET. But that's conditioned upon soil moisture is available, vegetation is in good health condition, environmental stresses are limited.

What I'm going to talk about is how remote sensing is going to help us estimate these limitations.

Actual ET, again, can be used for monitoring and assessment purposes, whereas potential ET is good for design purposes and planning purposes. Once we have actual ET, we can monitor drought. We can monitor water resource conditions.

How do we estimate actual ET? There are two principles. One is the mass balance or the water balance, and the other one is energy balance. The evapotranspiration process is a movement of water, which is mass. It's also a transfer of energy from a liquid to gas.

If you have good precipitation, rainfall data, you can use a mass balance approach. Or, what you are measuring is really temperature difference, which is one way of expressing energy differences. That, you could use an energy balance approach.

Where is the remote sensing coming in? Remote sensing is a data source. For land surface temperature, we use satellite data coming from Landsat, about 100-meters resolution, or MODIS AVHRR 1-km. Or, if our interest is global, we use the geostationary satellites. That gives you 10-kilometer data.

Again, if you are doing a water balance approach, the most important information is getting precipitation information. For the US, we have daily data from NOAA NEXRAD, at five-kilometer resolution. For global data, we have NASA TRMM at 25-kilometer or a European satellite called Meteosat at 10-kilometer resolution.

Just as an example to show contrast and then complementarity between the potential ET and actual ET, I'm showing you now just one year, for 2005 in Arizona. The yellow line, what you see on top, is rainfall. The green line is the potential ET. Somewhere around May, June, the potential ET in Arizona is high, as you would expect, whereas the actual ET is very low, because moisture is not available.

The monsoon season comes in July/August. As you can see, the potential ET and the actual ET become very close, because moisture is available to meet the atmospheric demand, which is the green line.

For a water balance approach, what we need is precipitation data, source information, some potential ET that Imtiaz described, and some water-budget accounting on a daily time scale to know the soil moisture status. That's pretty much a water balance approach, because evapotranspiration, again, is a function of soil moisture.

With that kind of water balance approach, we can obtain potential ET and also actual ET. On the bottom, what you see is modeled and observed with the flux tower. There is very good agreement in some of the methods we use.

What are the limitations of water balance? Most of the presentation's going to be on energy balance approaches in satellite data. Just want to point out why we are not using water balance as much, which means we need to get good rainfall data, which is not a problem in the US. In other parts of the world, getting good rainfall data, gridded data, is difficult.

More importantly, we don't know how much the farmers are applying. If that information is not there, we cannot really monitor irrigation water use through our water balance approach. We don't know how much they're applying. That's why an energy balance approach, which measures the temperature of the land, is a more practical approach.

A direct estimation of landscape stress can be measured using the remote sensing thermal data. From now on, I'll be talking about how the temperature of the land surface is used to get actual ET.

When we do an energy balance approach, again, we're monitoring the temperature changes across the landscape, we are accounting for water stress, agronomic stress, and environmental stress. All the stresses are combined and expressed in changes in land surface temperature.

This is an example of, CONUS-wide and parts of Mexico, annual ET, actual ET, how much the landscape is evapotranspiring. As you'd expect, in the Southeastern U.S., where there's an energy demand, the potential ET's high, but also soil moisture or rainfall is high, you'd expect a higher evapotranspiration.

On the Western U.S., on the other hand, actual ET is much lower. But if you see a potential ET map of this, the potential ET is much higher in the Western U.S. What's actually being responded by the landscape is much lower -- except irrigated lands like the Central Valley areas.

The method we developed at the USGS EROS has a very simplified approach. It requires potential ET, again, to know the maximum demand of the atmosphere, but the limitations come from the land surface temperature. We use air temperature to parameterize it, and then we come up with an ET fraction that varies from zero to one. Pretty much, we are scaling the potential ET.

The equation can be simplified further. Without going into the details, this actual ET is we're subtracting the fraction. We're just taking away the limitation from the potential ET. If this item is pretty much zero, the actual ET will be the same as the potential ET.

The limitation is expressed by the difference between the land surface temperature, which is a skin temperature, as compared to the air temperature. When the difference is close to zero, which means there is no sense of heat transfer, all the energy transfer is in the form of latent heat, which is evaporative cooling.

That makes this term pretty much zero, which means our actual ET is comparable to the potential ET.

Satellites provide this data, and this comes from meteorological data. The most important information is really the difference between land surface temperature and air temperature.

Just one more slide, and then I will show in our examples how important land surface temperature is, how dynamic it is. I'm showing you an ARC transect from the mountains of New Mexico, all the way to parts of Oklahoma, Arkansas. The mountains are in here on the west side and the plains on the east.

What you see in the middle is the land surface temperature by MODIS for a given day, July 4, 2012. As you can see in here, as you go into the mountain, the land surface temperature dips. As we know, as you go into the mountains, it becomes cooler. Then it dries up. As you can see, it goes up and down and up and down.

Now a comparison with an air temperature, as you'd expect, the temperature is also cooler in the mountains, but air temperature changes very, very slowly. That's why we call it a regional variable. It does not vary at a local scale. Whereas, land surface temperature varies very highly, because the local variable depends also on soil moisture and evaporative cooling.

This is a repeat. The land surface temperatures come from satellite, Landsat or MODIS, air temperature for model parameterization comes from different sources, and the potential ET comes from GDAS, NLDAS, GRIDMET that Imtiaz talked about.

Satellite data, as a lot of you may be familiar with, we have from MODIS. We have that almost twice a day, the land surface temperatures 1-km for the whole world.

MODIS has got, for example, 36 bands, and two of them are in the thermal in the east on the right side of the graph. Those are converted to land surface temperatures by NASA and is freely available for anybody in the world.

An example of land surface temperature map is shown in here, an eight-day average for the globe. As you would expect, the Sahara is warmer, that's where soil moisture is not available. Potential ET is a solution of the Penman-Monteith equation. We also have produced this at EROS for the globe, but for the U.S., there are better data sources. This data, again, are freely available for anybody.

As I said earlier, actual ET is a monitoring product, so we monitor the landscape. This would be, being absolute magnitude, what I'm going to show you is actually anomaly, a deviation from the median.

This is, for example, for the growing season in 2015 from April to October. As you see, greener colors are above normal conditions, when rainfall is much available, so it is much higher for that period, whereas brown colors are below normal conditions, which means drier conditions.

That's 2015. Now I'm going to show more years. That's 2014. Again, in California and northwestern U.S. dry conditions, but also Texas in 2014.

I'm going to show you now more years. 2011, the drought in, if you remember, Texas, Oklahoma and in 2012, that Imtiaz also showed, widespread drought in much of the U.S. 2013, again, repeat drought in this part of the U.S.

You can go back to 2000 at the start of the MODIS satellite era and noticeable drought years are 2002 and also 2006 in much of the high plains. This demonstrates that the satellite-based data is really helpful in capturing drought conditions at 1-km scale.

How does this also compare to Drought Monitor? That's a few slides on comparison to Drought Monitor. This is, for example, from previous year, 2016. There is a timescale issue, as Imtiaz showed. This is a seasonal product what you see on the right. This is a seasonal value and the Drought Monitor is just a weekly product for August 16th.

There is generally a match in different slots but is not exact. If you look at one month like July, the intensity would be here. What we do is we try to find different ways to compare the two products one-to-one.

This is a more current product. What is shown here is from our global ET anomaly product. It's hard to see. Generally, much of the world is really doing well. This is from October to March. This is mainly a growing season for the Southern Hemisphere, but generally the wetter conditions for the world.

As you come to the US, it shows dryness in the southeast and also even parts of the central plains in here, especially eastern Colorado, as well.

How does it compare to a weekly product of Drought Monitor? As you can see in here, there are also some decent comparisons in southeastern U.S., also central U.S. Again, there is a difference in time periods.

What we try to do is, how about if we aggregate the Drought Monitor and then there will be a more comparable, temporal match. I'm going to show you that on the following few slides. For example, from the part of the North Central Climate Science Center study with Dennis Ojima and Bob Flynn, they did this work.

This is our product from April to October, drought anomaly from actual ET. We aggregated the Drought Monitor from June, July, August. You can see a very good comparison when we are looking at comparable time periods.

I'm going to show another year. This will be 2012. A widespread drought anomaly report from Drought Monitor and the same from automated processing of remote sensing.

This would be 2013. Again, Drought Monitor doesn't show you when it's above normal conditions, but you see anomaly from remote sensing. The green shows you above normal conditions, but generally they are a very good match in here.

This is 2014. Again, you can see the epicenter of the drought here in the center and comparable depictions in here. The advantage of this is a 1-km resolution, as there is a lot more detail.

I'm going to show you now, how does this also help us understand water budget conditions in river basins and stream flows. One way of looking at it is, we have to combine ET with other supplies like precipitation and runoff.

Precipitation being a driver...this is the whole Missouri river basin. This is a new product, which is a preliminary result I'm showing you. As you would expect, there is higher precipitation towards the mouth of the Missouri river and lower precipitation in the headwaters.

As you can see, there is a general gradient in here, and how does this look from ET point of view. This would be the response of the landscape as a result of this precipitation. This precipitation comes in here, this is what you see in how the landscape used the water. If it's not used in the form of ET, it's probably runoff or recharge the groundwater.

As you would expect, higher rainfall areas give denser vegetation and more evapotranspiration, but much lower ET over here. The difference between the ET and the precipitation is, there is a lot more fine detail in here, because there is a higher spatial dynamic in vegetation as compared to rainfall. That is at annual time scale.

When you convert this ET in terms of anomaly compared to the median year, then it would show you pretty much what I showed you for the U.S., but this is for the basin. A lot of drought years in the 2000s, peak drought in 2002 for the basin. Another major drought in 2006, but generally drought years from 2000-2007 to more recent years, and then from 2009 on, really, the drought appears to be disappearing.

No drought in 2009, 2011 and then of course in 2012 it came, and then really wetter period until 2015, as well. This remotely-sensed drought data helps us understand, also look back in history, 2000 with MODIS, if we go to Landsat, we can go back to 1980s.

Just this slide to finish it up, what I showed you earlier. If you look at the water budget, what in here is year by year, the three important water budget components. Precipitation in blue, ET, and what's remaining is runoff. In ideal conditions, generally at annual timescale, the three of them, they add up to zero. Because this is the driver precipitation, it's being split into ET and runoff.

As you see, precipitation being important, the drought years I highlighted them here, they show up. Precipitation's lower, as you would expect, ET will be lower and also runoff will be lower. What you see on the lower right graph is the seasonal dynamics and month by month variability of the different components.

The peak precipitation happens by June, whereas the peak ET occurs in July where energy demand is high in July, but vegetation is also more dense. Having remote sensing to derive a variable like this will help us understand water budget distributions.

I think our time is running short, so I will hand over now. This is pretty much the summary of what I said. Imtiaz has got a few more concluding slides.

Imtiaz: Thank you, Gabriel. I'll conclude with a few more slides, primarily talking about the two terms we walked through today. As I collaborate with Gabriel on integrating these two data sets in a way that could bring about more robustness to our understanding of drought mechanism and more robust monitoring, as well.

Gabriel mentioned the complimentary relationship between potential ET and actual ET. Looking at conditions of these two terms and exploring here the processes of drought development and dissipation. It is a conceptual framework and then we look at the real data and see how it behaves in different parts of the country.

One way you can actually do right away is look at both EDDI and actual ET anomaly too, and compare the different time scales and explore how, in different regions, drought's persisting or emerging or the state of what kind of drought stress there is.

This is an example from July 2016. It was a high EDDI in the Texas-New Mexico region, and it was also a low actual ET anomaly. That tells you there's some severe drought stress out there and it's likely to persist.

Whereas if you can look at another location here, somewhere in the mid-Atlantic, you see that the conditions are...the AET is near-normal or slightly above normal but there's an emerging evaporative demand, so we can keep an eye for drought emergence in that region.

Just a couple of examples of how you...we've been looking at these processes on these products and exploring how to bring together these two information, high-resolution to get a much more robust understanding of drought mechanisms.

As we go into Q&A, I'll leave you all but this slide on resources, and there are many more of these out there and in process of development. Thank you for your attention.

Ashley: Excellent, thank you so much.

Robin O'Malley: Hi, Ashley. This is Robin O'Malley. Can you hear me?

Ashley: Yes, I can. Hi, Robin.

Robin: Hi, can I ask a question?

Ashley: Please.

Robin: This is a question for Imtiaz. I'm interested in the projection and prediction possibilities here. You showed a couple of cases where you showed us an EDDI set of observations, and then later on you showed the Drought Monitor and obviously, there's an early warning component to that.

Have you looked at that enough to be able to say at any point, if EDDI is here and conditions don't improve, the Drought Monitor will end up in a four or a five? If it keeps going down and things

stay bad, here's where it will bottom out or if we get rain, it may only end up? The shape of the evolution curve, could you start to get a sense of how deep a drought will be if it continues? Is that a possibility?

Imtiaz: Thanks, Robin. That's a great question. Yea, the developers of EDDI, they're based in NOAA and the Desert Research Institute have a paper out there in terms of forecasting EDDI, where they see there's probably more skill than forecasting precipitation on a sub-seasonal timescale because variables like temperature and radiation and others may be more skillful for forecasting at those timescales.

So yes, and that product is not operational right now, it's still in an experimental phase. It's being done and it would be interesting to see what kind of skill it has in doing that, but that's very much in the pipeline, so right thinking there.

Robin: Thanks.

Ashley: Thanks, Robin. Are there any additional questions? I apologize, but my Adobe Connect has lost connectivity, so if you're typing into the chat box, I cannot see that at the moment.

Imtiaz: I can see it. The question by Dominique is, can you relate change in ET to changes in vegetation cover with any precision? Gabriel, would you like to take that?

Gabriel: Sure. ET is a function of, of course, the potential atmospheric demand, but also the vegetation composition, type, stage, and also soil moisture. Different vegetation types, whether because of their structure or their water use, they will reflect differently, so it should show.

The good thing is we don't need to know the vegetation type to model its ET, but you can use vegetation cover to understand how much different vegetation covers are responding. Yes, different vegetation covers should show, but if it is a small, patchy area, we have to use a higher resolution data like Landsat or even smaller, but if you are interested in basin scale, then MODIS 1-km.

Really, the challenge is, do we have the special resolution from a satellite. In terms of different vegetation showing different ET response, yes, that happens.

Imtiaz: Our question was, follow-up was, can we detect invasives in deserts if we have a high flux of precip?

Gabriel: Yeah. Again, the quality of the data we're getting is the same thing in the desert and shrub lands, as well. If it is a small amount of ET, like very high desert areas, then our accuracy will be working close to the margin of error. That depends on then getting really a higher quality remote sensing data, higher spatial resolution and more frequent data, but the response will be captured if you have the data.

Ashley: Thank you.

Imtiaz: I see another question out there typed by Ryan for use of EDDI and how sensitive EDDI is to underlying reference vegetation.

That's a good question there, because EDDI is calculated using a reference evapotranspiration and reference, really, is reference condition. These are reference crops, and so what's the applicability to other slices, and I guess that's where this question is going.

EDDI is, really, looking at the anomalies. If you were looking at absolute values of reference evapotranspiration, there would be an issue, but we feel that the anomalies really work with the atmospheric side of this story.

Although, as we're working with gridded temperature and humidity data that are controlled by land surface moisture conditions, but primarily it's the atmospheric side of the story. The reference vegetation in the context of EDDI do not matter that much to the kind of information it's providing.

Ashley: Excellent, thank you.

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